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PROGRAM MANAGEMENT COURSE
INDIVIDUAL STUDY PROGRAM

CONFIGURATION MANAGEMENT
for the
Development of
Computer Systems

Study Project Report
PMC 76-2

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DEFENSE SYSTEMS MANAGEMENT SCHOOL

STUDY TITLE: CONFIGURATION MANAGEMENT FOR THE DEVELOPMENT OF COMPUTER SYSTEMS

STUDY PROJECT GOALS:

1. Identify configuration management requirements for major defense systems development.
2. Translate these requirements to a computer system environment.
3. Present a general approach to configuration management for the Base Level Data Automation Program (Phase IV).

STUDY REPORT ABSTRACT:

This study examines configuration management as defined in Department of Defense publications for major defense systems and applies configuration management to the development of computer systems. DOD Directives, DOD Instructions, Military Standards, and Air Force publications provide the primary source of configuration management principles and functions. Configuration management has had limited application to embedded computer systems and even less to general purpose computer systems. The study discusses configuration management principles in the computer system environment and concludes that these principles can be and should be applied to the development of computer systems. To demonstrate that conclusion, the principles are applied to a specific Air Force program, the Base Level Data Automation Program (Phase IV).

Key words: Configuration Management, Computer Software.

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CONFIGURATION MANAGEMENT

for the

Development of

Computer Systems

Study Project Report

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by

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MAJ USAF

November 1976

Study Project Advisor
Mr. Edward Speca

EXECUIVE SUMMARY

The increasing complexity, cost, and dependence on computer systems demand better management of their development. Configuration Management is one component of the total management structure where considerable improvement is needed. Configuration Management is a well-defined discipline when applied to classical major defense system development where hardware is the primary end item. Most of the publications within the Department of Defense consider Configuration Management a vital part of controlling development and there is considerable guidance available. However, Configuration Management has had limited application to embedded computer systems and even less to general purpose computer systems. Configuration Management principles are examined to determine if the discipline defined for major defense systems can be applied to the development of computer systems.

Configuration Management consists of three functions; configuration identification which identifies the baseline configuration of a configuration item, configuration control which controls all changes to the baseline, and configuration status accounting which tracks and reports status of configuration items and applicable changes.

Reviews and Audits are a part of the Configuration Management process and provide a method for accomplishing the three functions and tie Configuration Management into the total development process.

It is concluded that the Configuration Management principles defined for the major defense system environment can be and should be applied to computer systems. Specific procedures will have to be adapted and tailored to the computer system development process, but the principles are valid.

The principles are then applied to an Air Force program, the Base Level Data Automation Program (Phase IV).

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CHAPTER I

Introduction

Problem: The US Air Force has experienced considerable difficulty in the recent past in the development of major computer systems such as the Advanced Logistics System (ALS), the Base Automated Systems for Total Operation (BASE-TOP), and the Tri-Service Medical Information System (TRIMIS). It is the opinion of this author that many of the difficulties were due to the system of management and control expressed in the Air Force 300 series regulations. These directives, while having served well for earlier development, do not provide adequate management of the development process required for today's large and complex systems. In contrast, the management of the defense system development process is well defined in the USAF 800 series regulations in conjunction with applicable Military Standards and DOD publications. This paper will focus on one aspect of this management process, that of Configuration Management (CM).

The directives within the Department of Defense that address CM are written for the acquisition process of major defense systems. When the subject of computer software/hardware is addressed, it is addressed in terms of an embedded computer system which is one component of the total defense system. There is considerable guidance on CM in this environment versus a limited amount for the development of computer systems. The term computer system is used in this paper to denote those computer system developments which are not directly related to a weapon system and with emphasis on computer software. Systems such as ALS, BASE-TOP, and TRIMIS are considered to be computer systems in this context. Because of the increasing complexity of computer systems there is a recognized need to improve the management of

their development.

Purpose: In view of the fact that additional CM guidance is needed for computer system development, the primary purpose of this paper is to examine the CM principles in the major defense system environment and assess their applicability to the computer system environment. Improved CM is one step in providing improved total program management.

Scope: This paper is intended to be academic in nature and confined primarily to the major principles and functions of CM. It is not intended to detail specific procedures nor develop a CM plan. There are examples and outlines of CM plans in various other documents. Chapter IV will, however, discuss these principles in relation to a specific Air Force program, the Base Level Data Automation Program (Phase IV).

Limitations: Configuration Management has been receiving increased attention at all levels in the Department of Defense and many of the applicable documents are in the process of extensive revision. This is especially true with respect to the Air Force documents. Hence, this report should be viewed by later readers in the time frame in which it is written. Secondly, the reader should be aware that the author has limited experience in CM. Part of the purpose in writing this report was to gain a better knowledge of CM activities. Thirdly, because of the limited time available for preparation, research on the topic was restricted primarily to existing documentation. A logical next step, once CM principles are understood, would be to investigate how these principles are actually employed at the operating level.

Organization: The paper is organized to provide the reader first with a familiarity for what publications address CM and what they generally contain.

Chapter III will attempt to provide an understanding of what CM is as defined in those publications and how the CM concepts apply to computer systems. Chapter IV will then discuss these concepts in relation to a specific Air Force program, Phase IV.

CHAPTER II

Current Policies and Directives

There are numerous publications which discuss Configuration Management (CM) and have an impact on CM activities. This chapter will discuss those considered most germane to the CM. To discuss these publications it is necessary to have a basic idea of what CM is. DODD 5010.19 defines CM as "a discipline applying technical and administrative direction and surveillance to (a) identify and document the functional and physical characteristics of a configuration item; (b) control changes to those characteristics; and (c) record and report change processing and implementation status." (12:2)[1]

The three key words are identify, control, and status. These are the three main functions of CM, often referred to as configuration identification, configuration control, and configuration status accounting. A detailed discussion of what these functions are and what they mean to CM will be given in the next chapter.

DOD Directives and Instructions: Probably what could be considered the root document of CM is DODD 5010.19, "Configuration Management." It contains overall policy guidance on the use of CM and defines some terms applicable to CM. It briefly explains the functions of CM, identification, control, and status accounting. It directs that CM be applied to "all CIs (Configuration Items) procured for use by the DOD or obtained through an agreement between in house activities." Once CM has been initiated for a CI, it will continue until the CI is removed from the operational inventory. (12:3)

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1. This notation will be used throughout the report for sources of quotations and references. The first number is the source listed in the Bibliography. The second is the page in the reference.

As stated in DODD 5010.19, objectives of CM are to (1) assist management in the development of a CI; (2) introduce controls at the appropriate time during development, but yet allow maximum latitude for design trade-offs; (3) efficiently manage changes; and (4) "attain the optimum degree of uniformity" across all organizations involved in the development of the CI. (12:2)

DODI 5010.21 covers the same CM functions and concepts introduced in DODD 5010.19 but in greater detail, clarifies some of the terms, and defines additional ones. Under configuration identification it discusses the functional, allocated and product configuration identifications which tie CM to the baselines established during the development cycle of a CI. These points are critical to the CM activity for it is from these baselines that the configuration is established and controlled. (13:2)

The discussion of configuration control identifies two types of changes, appropriately called Class I and Class II. Class I changes are of such significance that they affect the Government's interest in that they affect the function, interfaces with other CIs, performance, costs, or delivery to the Government. Class I changes require the approval of the Government. Class II changes are of minor significance and consist primarily of small changes to effect correction of documentation or detail design. (13:4)

This instruction also expands on configuration audits, specifically a Functional Configuration Audit (FCA) and a Physical Configuration Audit (PCA). The FCA is a "means of validating that development of a CI has been completed satisfactorily, i.e.,that the item will perform as intended." The PCA establishes that the CI produced matches its configuration identification. (13:9)

Several other documents mention CM and usually refer to one of the documents described above. For instance, DODD 5000.29, "Management of Computer Resources in Major Defense Systems," mentions CM in paragraph V, Policy. It states simply, "Defense System computer resources, including both computer hardware and computer software will be specified and treated as configuration items. Baseline implementation guidance for this action is contained in DODI 5010.21." (11:2)

It should be noted that these documents are usually interpreted to apply CM to the major defense system acquisition process. As a point in contrast, DODI 5010.27, "Management of Automated Data System Development," which could be considered the top document for development of computer systems, neither mentions CM nor uses as reference any CM related document. Even at the highest levels there has been, to date, little consideration of the importance of CM to the development of computer systems. The problem has just begun to surface because of recent software difficulties resulting from the growing complexity of software both for major defense systems and general purpose support.

Military Standards: The primary military standards that deal with CM are 480, 481, 482, 483, 490 and 1521. No one document covers the CM spectrum, but Mil-Std 483 is probably the most comprehensive in that regard. Mil-Std 483, "Configuration Management Practices for Systems, Equipment, Munitions, and Computer Programs," is broken into two parts. The first part gives the general requirements for CM. The second part provides a number of appendices which are intended to provide guidance for the preparation of documents related to CM and not covered in other Mil-Stds. It establishes supplementary requirements in the following configuration management areas:

a. Configuration Management Plan

b. Configuration Identification

c. Interface Control

d. Configuration Audits

e. Engineering Release Control and Control of Engineering Changes

f. Configuration Management Reports/Records (3:1)

The other Mil-Stds go into great detail on one specific aspect of CM. Mil-Std 490, "Specification Practices," describes the various specifications. The specification documents identify the configuration. Hence, Mil-Std 490 is aimed at the configuration identification function of CM.

Mil-Std 480, "Configuration Control-Engineering Changes, Deviations and Waivers," and Mil-Std 481, "Configuration Control-Engineering Changes, Deviations and Waivers (short form)," are aimed at configuration control. Mil-Std 482, "Configuration Status Accounting Data Elements and Related Features," provides guidance for the third CM function status accounting. Mil-Std 1521, "Technical Reviews and Audits for Systems, Equipment, and Computer Programs," describes a review and audit process.

Reviews and audits are a key element in the development of any system. Depending on the point of view, a system of reviews could be either included or excluded as part of CM. The FCA and PCA are traditionally considered a CM function. While other reviews may not technically be a part of the CM definition, they play a key role for the Configuration Manager. Since they tie directly to the approval of specifications for the configuration identification function, the approval of changes for configuration control, and the audit of the actual configuration for the status accounting function, the reviews and audits are often treated as a part of the responsibility of the Configuration Manager. They will be so treated for the purpose of this paper.

In sum, this set of Mil-Stds provide considerable guidance for CM. As with the DOD directives, these standards, when addressing computer programs, do so primarily in terms of a computer program being part of a major defense system.

Air Force Publications: The Air Force documents that address CM are based on the DOD and Mil-Std documents just discussed. Much of the terminology is consistent with these documents. AFSCP 800-3, "A Guide for Program Management," discusses CM as it applies to Program Management. Chapter 9 gives an excellent synopsis of the entire spectrum of CM to include Configuration Audits. AFR 65-3, "Configuration Management," is a joint service regulation which attempts to implement DOD policy and guidance. AFSCM/AFLCM 375-7, "Systems Management Configuration Management for Systems, Equipment, Munitions and Computer Programs," goes into great detail about every aspect of CM. Because of this detail it loses some of its effectiveness. However, used as a guide, it can be of considerable help to the configuration manager in preparing the CM plan and establishing CM procedures. AFR 800-14, "Acquisition and Support Procedures for Computer Resources in Systems," addresses CM of computer resources more directly. It attempts to differentiate CM during the validation, full-scale development and early production phases versus the later production and deployment phases when emphasis changes from identification to change control. It also provides for the establishment of a Computer Program Configuration Sub-Board as a subordinate element to the Change Control Board, for the purpose of reviewing Computer Program Configuration Item (CPCI) changes which do not affect system equipment. These publications are all pointed to the major defense system acquisition process and address computer systems only as a part of that process.

To date, the acquisition and development of computer systems within the Air Force have followed the 300 series publications, which describe a quite different process. With respect to CM specifically, only fleeting references are made. Some of the classical CM functions are mentioned under the guise of phrases such as control of design and development and Automatic Data Processing Systems (ADPS) management, but there is no defined discipline for CM. However, within the last 12 months, the Director of Data Automation of the Air Force has recognized that the process of ADPS acquisition and management needs to be strengthened. One of the areas receiving much emphasis is configuration management.

The DOD, Mil-Std, and Air Force publications discussed in this chapter are the primary ones concerned with CM. There is notably a lack of guidance in the computer systems area and specifically for those systems not related to major defense systems. It may be significant to observe that the DOD publications and the Mil-Stds were published to a large extent between 1968 and 1970. The size and complexity of embedded computer systems as well as general computer systems have grown considerably in just the last 6 years. The need for applying CM to embedded computer systems, particularly software, is just now emerging. The Air Force has also recognized the need for CM on systems being developed on general purpose equipment. The next chapter will relate the CM principles in the publications discussed to the environment of the latter.

CHAPTER III

Configuration Management

In the previous chapter the primary directives which pertain to Configuration Management were discussed. This chapter will describe how CM concepts transfer to the computer system environment.

Computer System Development Cycle: It is first necessary to have an understanding of the development cycle for a computer system. The major phases are quite similar to those depicted for major defense systems. The activities within these phases, however, differ significantly at some points.

While most papers that address the computer development cycle discuss the same general concepts and steps, there is no generally accepted agreement on the nomenclature nor groupings of the steps. For the purpose of this paper, the cycle described in the Air Force Data System Design Center Manual (AFDSDCM) 300-8 (test) will be used. This manual is in a test phase and is one of the first documents addressing computer systems produced by the Air Force which incorporates some of the management techniques used in major defense system development.

The development process described in the manual consists of five phases: (1) conceptual, (2) definition, (3) development, (4) test, and (5) operations.

The conceptual phase covers the writing, approving and reviewing of requirements for data automation support. During this phase the user identifies and justifies the need for Automatic Data Processing (ADP) support to fulfill a mission or operational requirement. The conceptual phase concludes with a Preliminary Requirements Review (PRR) which approves or

disapproves further work. (5:2-9)

The definition phase has three primary tasks. One is to develop a Functional Description (FD) which is a detailed description of the functional process being considered for ADP support. It describes "the logical work flows of activities and events and information flow in the existing user environment." (1:2-10) The second task in this phase is to develop a Data Project Plan (DPP). This plan is a comprehensive management plan describing how the project will be developed, who the players are, the milestone schedule, and the resources required. It is a description of the action necessary to achieve system performance, project schedule and cost objectives. (1:2-10, 1:A2-2) The third task is to develop alternative methods for satisfying the requirement. These alternatives are evaluated and a recommended method is proposed for concept certification at the System Requirements Review (SRR). The FD identifies the functional baseline. The FD and DPP remain "live" documents throughout the life of the system.

Once concept certification has been granted, the project moves to the development phase. During this phase detailed design is completed. Before programming begins the design is reviewed and approved which establishes the allocated baseline. The development phase ends when the programming and checkout are completed.

During the test phase, the systems software and documentation are thoroughly evaluated both at the development facility and at test field sites. Both the product and operational baselines are established during this phase. (1:2-10)

During the final phase, the operations phase, the system is transferred from the developer to the user going through an implementation/conversion

period. An operational evaluation is provided to the developer by the user after a period of operation. Maintenance and product improvement continue throughout the life of the system. Major modifications will normally go through the full development cycle before incorporation into the operational system.

AFDSDCM 300-8 (test) breaks these phases into 17 steps shown in figure 1 which is taken from the manual. Of particular interest for this paper, is the fact that the figure shows configuration management beginning during the definition phase.

Using this computer system development cycle as a basis, lets look at how the configuration management concepts described briefly in Chapter II for major defense systems, translate to the computer system environment.

The management of computer system development has problems which are unique and management techniques used for the hardware of major defense systems cannot be transferred en tote. Some of the obvious differences are:

1. Computer projects often produce a one of a kind item as opposed to the production of a quantity of the same item. Hence, the major portion of the cost is all at the front end and cannot be amortized over a production quantity.

2. Computer projects are not concerned with the logistics of spare parts. There are no spares. The problem of maintainability is in an entirely different context.

3. Computer projects are more concerned with the functional design requirements, than with the physical design. The crux of a successful computer system is the reliability of the software and whether it performs the required mission.

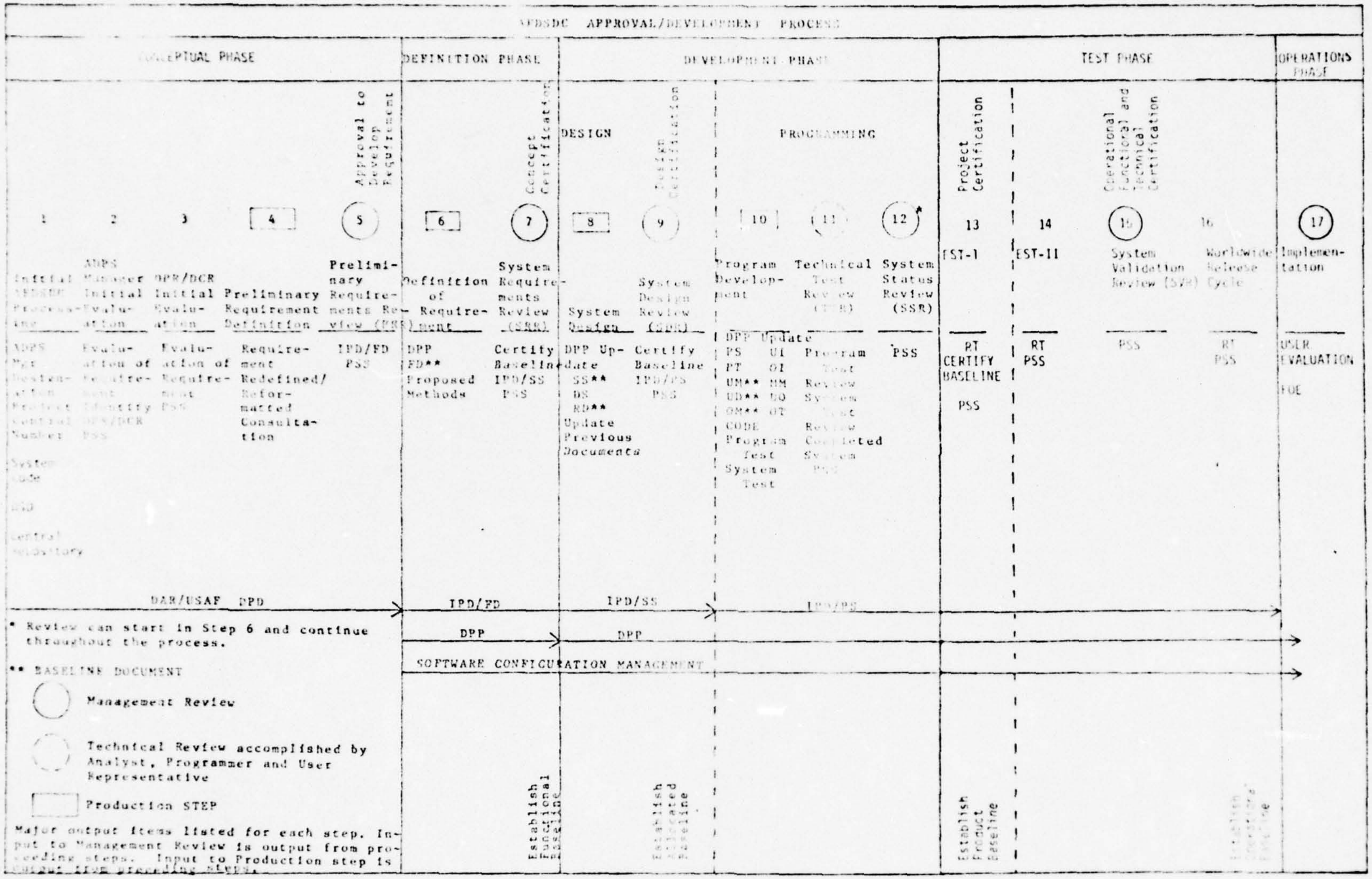
APPROVAL/DEVELOPMENT PROCESS
DEFINITION PHASE
DEVELOPMENT PHASE
TEST PHASE
OPERATIONS PHASE
Approval to Develop Requirement
Concept Certification
DESIGN
PROGRAMMING
Project Certification
Operational Functional and Technical Certification
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17
ADPS Manager Initial Evaluation
DPR/DCR Initial Evaluation
Preliminary Requirement Definition
Preliminary Requirements Review (PRR)
Definition of Requirement
System Requirements Review (SRR)
System Design
System Design Review (SDR)
Program Development
Technical Test Review (TTR)
System Status Review (SSR)
EST-I
EST-II
System Validation Review (SVR)
Worldwide Release Cycle
Implementation
Evaluation of Requirement Identify DPR/DCR PSS
Evaluation of Requirement PSS
Requirement Redefined/ Reformatted Consultation
IPD/FD PSS
DPP FD** Proposed Methods
Certify Baseline IPD/SS PSS
DPP Update SS** DS RD** Update Previous Documents
Certify Baseline IPD/PS PSS
DPP Update PS UI PT OI UM** MM UD** DO OM** OT CODE Program Test System Test
Program Test Review System Test Review Completed System PSS
PSS
RT CERTIFY BASELINE PSS
RT PSS
PSS
RT PSS
USER EVALUATION FOE
DAR/USAF PPD
IPD/FD
IPD/SS
IPD/PS
DPP
DPP
SOFTWARE CONFIGURATION MANAGEMENT
* Review can start in Step 6 and continue throughout the process.
** BASELINE DOCUMENT
Management Review
Technical Review accomplished by Analyst, Programmer and User Representative
Production STEP
Major output items listed for each step. Input to Management Review is output from preceding steps. Input to Production step is output from preceding steps.
Establish Functional Baseline
Establish Allocated Baseline
Establish Product Baseline
Establish Operational Baseline

Figure 1

4. Changes to computer programs require a complete retesting of the program module to verify that the change has not impacted the program function or caused an interface problem with other modules. (14:3)

In the specific discipline of configuration management, however, the concepts applied to hardware have much to offer the CM of computer systems. While some of the specific procedures must be different, the basic concepts can be applied. The rest of this chapter will discuss how the concepts of CM apply to computer systems development.

Configuration Identification: Configuration identification is "the current approved or conditionally approved technical documentation for a configuration item as set forth in specifications, drawing and associated lists, and documents referenced therein." (12:2) The configuration item (CI) in terms of software is a computer program or set of computer programs, designated as a Computer Program Configuration Item (CPCI). However, not every computer program should be a CPCI. As with hardware, CPCIs should be identified based on whether they satisfy an end use function, are key programs, have expected interface problems or, in the judgment of the Program Manager, to provide added visibility to a particular computer program. Because of this selectivity, a CPCI may vary greatly in program size. A CPCI can be broken into one or more computer program components (CPC) which can be thought of as a performing one of more of the sub-functions necessary to accomplish the end item function of the CPCI.

The technical documentation for a CPCI is not the same as for hardware CI. In Air Force terminology, the technical documentation consists primarily of a System/Subsystem Specification (SS) and a Program Specification (PS). The SS specifies system performance, interfaces with other CPCIs, data requirements and other technical requirements in sufficient

detail to permit detailed design of the system components. The SS is the document which is reviewed at the System Design Review and identifies the allocated baseline. (6:3-6)

A PS is usually written for each CPC of the CPCI. It consists of the detailed technical description of the CPC, the flow charts, interfaces with other CPCs and when completed, a listing of the actual computer instructions. (6:4-10)

The SS and PS are somewhat analogous to the Part I and Part II specifications described in Mil-Std 490. There are often other documents required to completely specify the CPCI or the relationship of one CPCI to another. The Data Requirements Documents (RD) lists and defines data elements that will be used within the CPCI. This can be a key document when developing systems with a large number of CPCIs since it defines the format and size of the data elements and provides standardization for common data elements. A second document which is related to the RD is the Data Base Specification (DS). The DS specifies the organization of the data elements within the computer and allows the programmer to generate the required files, tapes, and dictionaries for the CPC. (6:12) The RD and DS are necessary in large systems to define the interfaces between CPCIs and CPCs. The documents and a suggested format are described in detail in DODM 4120.17, "Automated Data Systems Documentation Standards Manual."

The function of configuration identification also includes the number and marking of CPCIs, CPCs and their documentation. The development of a numbering and marking scheme is another subject within itself and will not be discussed here. Some of the things that need to be considered in developing that scheme are the documents that are to be numbered. These may include more than just the specification documents such as users manuals,

test reports, or management plans. The CPCI number, CPC number, version number, version description document number, change identification numbers all need to be considered as well as identifiers to be used within the computer itself to mark tapes, disc packs or other storage media for programs and data files. (22:21)

Configuration Control: Configuration Control is the "systematic evaluation, coordination, approval or disapproval, and implementation of all approved changes in the configuration of a CI after formal establishment of its configuration identification." (12:2) For CPCIs, configuration control consists of managing the changes which affect the baselines.

It is appropriate at this point to digress and discuss the idea of baseline management. Baseline management is a key concept to configuration management. The baseline is the reference point on which further development and control are based. Documents are identified which describe that baseline and any changes must be approved, controlled and documented. The following baselines are usually established during the development of the system.

1. Functional baseline. This baseline provides the detailed definition of what the user says is required. The functional baseline is established at the System Requirements Review which approves the Functional Description (FD) document as well as the methodology for satisfying the requirement.

2. Allocated baseline. This baseline provides the system definition of how the requirements in the FD are to be satisfied. The System/Subsystem specification (SS) is the applicable document and its approval at the Systems Design Review establishes the allocated baseline.

3. Product baseline. This baseline provides detailed design of

the CPCIs and CPCs required to perform the functions required by the SS. The principle document is the Program Specification (PS). The product baseline is established after developer testing is completed, but prior to operational field testing.

4. Operational baseline. Once the operational test has been satisfactorily completed, the system is ready for implementation. At this point the operational baseline is established. This baseline is really a refinement of the product baseline and includes corrections made by the developer for errors discovered during field testing. (A field test is a joint test coducted by the developer and user under operational conditions.) Other documents may come under configuration control at this time such as the users manual, computer operators manual, and maintenance manual. (1:2-9)

Any changes to these baselines, once established, must be controlled. The process of approval and control is the function of configuration control.

There are two types of changes, Class I and Class II. Class I changes are those changes which are of such significance that it affects one of the established baselines in terms of performance, schedule, cost or user requirements. Class II changes do not affect the technical content of the baseline documents and are typically minor corrections to documentation or programming errors.

As with hardware, changes are initiated via an Engineering Change Proposal (ECP). However, DD Form 1692, ECP, should not be required. A form more appropriate to software changes should be designed for use during the computer system development. AFR 300-xx contains a recommended ECP form for computer systems. Each ECP is required to define the proposed change, the need or justification for the change, impacts on any other part of the system functions, estimated resources, both cost and manpower, and a

milestone schedule for accomplishment. (6:27)

A major role in the control of the changes is played by the Configuration Control Board (CCB). The CCB must review and evaluate, and approve/disapprove all Class I changes. The priority of Class I changes can be the same or similar to that described in DODI 5010.21 as emergency, urgent, and routine. Software changes will have to be made on the same basis. It is important to recognize that both the documentation and the operational program need to be controlled. A computer program is an intangible product and if strict procedures for implementing changes are not established, programmers will, because of their nature, tend to put "small" changes into the system which have an affinity for having a greater impact than the programmer anticipated or realized. Once a Class I change is approved it goes through much the same development and test process that the original system went through.

The changes to the configuration documentation and the computer programs must be rigidly controlled and processed and approved in a systematic way. Changes must be tracked and reviewed much the same as in the original development. The third function of CM does this record keeping.

Configuration Status Accounting: Configuration Status Accounting is "the recording and reporting of the information that is needed to manage configuration effectively, including a listing of the approved configuration identification, the status of proposed changes to configuration, and the implementation status of approved changes." (12:2) For computer systems it involves the recording and reporting of the identification and status of the evolving CPCIs, provides traceability of past problems, corrective actions, status of changes in process and the responsible office(s) working the changes, and maintaining the correlation between the documentation and

the computer programs.

Configuration status accounting is primarily a bookkeeping function. To keep track of the information a series of logs is designed. If the size of the system is large enough it may be desirable to automate the record keeping. Various types of logs and indices are suggested by references 6 and 23. A key one is the configuration index which provides the status of each CPCI and the proposed changes to the CPCI. Each CPCI is entered into the configuration index as it is identified and baselined. As development of the CPCI continues the configuration index is updated to reflect the latest status. The CPCI is in the configuration index throughout the life of the CPCI.

In addition to the documents which specify the configuration, the status of each document such as the users manual, maintenance manual, description document, and computer operators manual should be tracked. These documents are also an important part of the function of the total system.

In short, Configuration Status Accounting supports the functions of identification and control by providing the record keeping necessary to maintain control. Another aspect of CM, which, while not a specific function of CM, is an integral part of the CM process is that aspect of the system of reviews and audits.

Reviews and Audits: A system of reviews and audits is the methodology by which CM performs its functions of identification and control. There are basically two kinds of reviews and audits. The first are the reviews which look at the requirements and design. These are scheduled at major milestones during the development cycle. The purpose of these reviews is to formally assess and approve/disapprove the work done to date and provide guidance for further efforts.

Referring again to Figure 1, the System Requirements Review marks the end of the definition phase and establishes the functional baseline. The System Design Review marks the end of system design and establishes the allocated baseline. The draft AFR 300-XX, reference 6, describes the conceptual phase and definition phase and their reviews in different words than AFDSDCM 300-8 (test), but the same activities occur and both result in the functional and allocated baselines being established as a result of a particular review.

The second kind of reviews and audits is verification oriented as opposed to management and approval oriented. A Functional Configuration Audit (FCA) and Physical Configuration Audit (PCA) are conducted during step 13 of Figure 1. The draft AFR 300-XX calls this activity the Product Verification Review of which the successful completion establishes the product baseline. The FCA in this context means a "formal examination of the test data for a configuration item's functional characteristics," while the PCA is "the formal examination of the coded version of a computer program configuration item against its technical documentation." (6:A-4,5) In other words, the FCA insures that the functions required by the SS are satisfied by the CPCI whereas the PCA matches the performance of the CPCI against its design specifications and associated manuals to insure that the documentation is complete.

The System Verification Review is conducted at the completion of all testing including field testing, and establishes the operational baseline certifying that the system is ready for distribution and operational use.

The system of reviews and audits provides the configuration management function with the necessary methods and formal approval steps from which to conduct the three functions of CM, identification, control and status

accounting. These reviews and audits tie the configuration manager into the total management of the development and also with the Quality Assurance function. The FCA and PCA are the first steps required for Quality Assurance and most likely will involve the participation of personnel from that function.

This chapter has discussed some of the principles of CM as used in major defense systems development and, with the assistance of some new and draft Air Force documents, has attempted to show their applicability to computer system development. There is much similarity, but the definition of functions and terms need to be adopted to the computer environment. However, the principles can be and should be applied. The next chapter tries to relate these principles to a specific Air Force program, The Base Level Data Automation Program (Phase IV).

CHAPTER IV

Configuration Management Principles

Applied to the Base Level Data Atomation Program (Phase IV)

Having looked at what CM is and how it generally applies in the computer system environment, let's look at how CM might apply in a specific program environment. The program that will be addressed is the Base Level Data Automation Program (Phase IV).

Background: The Phase IV program is a program to replace the standard computers installed at major Air Force bases throughout the world. The Air Force currently has two standard computers. One is the U1050-II which is used to process the Standard Base Supply System (SBSS). This computer has been in use since 1963 and is located at 126 sites. The other standard computer is the compatible set of B3500/B4700 computers which is located at 117 sites. The Burroughs computers have been in use since 1968 and are used to provide general purpose computing support to such functional areas as finance, personnel, civil engineering, vehicle maintenance, medical, etc. In addition, a Remote Job Entry Terminal System (RJETS) is being used to provide support to small Air Force facilities, the Air Force Reserve, and the Air National Guard. (10:2,20)(20:A-1)

These two standard computers have reached the point where it is no longer considered economical to repair nor feasible to further augment their inherent capabilities. The Air Force has concluded that it is necessary to replace these computers with a family of computers which are compatible with each other and can be sized to accommodate the different computer loading requirements of the various Air Force installations. The program received concept certification on 12 October 1976 and has just

formally moved into the definition phase. Considerable work has, however, already been done for the definition phase because of work accomplished on two previous programs recently cancelled that had similar objectives.

The Phase IV program has targeted world-wide implementation to begin in mid-1981. Initially, this may seem like a long lead time, but in examining the steps necessary to reach that point with their associated time consumption, mid-1981 may be optimistic. One of the big time eaters is the procurement process which is planned to take over 2 years for developing the Request for Proposal (RFP), evaluating the proposals and making the contract award. This schedule, in my opinion, is not at all pessimistic. Because of the size of the equipment procurement, past Air Force experience indicates the selection will be highly competitive and fraught with problems.

The transition of the software is also a sizeable task and involves a large number of organizations. For the B3500/B4700 alone, there are over 600 different software systems consisting of over 7000 programs and over 20 responsible organizations involved. Software of this magnitude and diversity will require a comprehensive, controlled, coordinated conversion effort. This presents a real management challenge. The Configuration Manager will play a key role in this process and will have a number of significant issues to deal with.

With the large number of programs involved, one of the first issues is to determine what level of control is needed and at what level CPCIs should be established--systems level or program level? In most cases it is expected that the CPCI should be established at the systems level. However, systems consisting of a large number of programs should be considered for breaking into several CPCIs. Each system needs to be examined to determine the level of control necessary. As stated in Chapter III, the designation

of a CPCI should be by the best judgment of the program management team, and not set arbitrarily.

A more slippery problem than the designation of CPCIs is defining the configuration baselines, the functional, allocated, product, and operational baselines. Since many of the systems to be transitioned have been operational for a number of years, any functional baseline in the text book sense has probably been long since obscured by many modifications, which have affected the original functional methodology as well as the operation of the system. This is also true to a certain extent of the allocated and product baselines. It would be difficult for the organization responsible for the CPCI to produce complete documentation to support these baselines. There is, however, an operational baseline that has been maintained by AFDSDC. The systems have evolved over a period of time and as they now exist meet a group of specifications instead of a single integrated one.

Configuration Identification: This situation presents a problem for the CM function of identification. Identification of CPCIs is based on having adequate documentation to describe the functional and systems requirements. If existing documentation does not adequately define the CM baselines, should additional documentation be generated to produce those documents normally associated with the baselines? The answer is somewhat dependent on how the software is to be transitioned. AFDSDC and the Phase IV Program Management Office (PMO) are considering four approaches for transition at the present time. These four are Translation, Reprogramming/Redesign, Simulation and Emulation. Simulation and emulation are, in my opinion, only temporary solutions since all systems must (or at least should) be eventually converted to run directly on the new hardware to take advantage of new features and techniques. The primary advantage of using these two methods is that the initial workload,

to get the system "on the air" with the new hardware, is reduced and it is probable that faster implementation would be achieved. This is contingent, of course, on the availability of an adequate simulator or emulator, or both.

Even for a direct translation effort, a reprogramming/redesign effort would seem appropriate at some future date. It is recognized that the first objective of the transition must be to get systems operational on the new hardware in the scheduled time frame. The second objective, to utilize the full capabilities of the new hardware, may have to take a back seat, but at some point reprogramming/redesign will have to be done.

If a reprogramming/redesign effort will occur, changes to the system must be reviewed and approved against the same baseline. In view of this, we may be inclined to answer the question posed earlier, concerning preparing additional documentation, with a yes, since both the functional and allocated baselines will change. There is, however, another aspect that needs to be considered before giving a definite answer.

Because the transition/implementation period is over an extended length of time, it would be undesirable to freeze the design of all systems at an early time and prohibit any further development and implementation of enhancements. Consequently, the Program Management Office is establishing three conversion baselines (these baselines should not be confused with the four CM baselines). These three baselines are the transition baseline, the implementation baseline, and the projected requirements baseline. The transition baseline consists of all currently operational systems or approved systems and enhancements scheduled for implementation on the B3500 or U1050 that will transition to the new Phase IV hardware. This includes general support software as well as application software. The implementation baseline is the transition baseline plus those systems or enhancements that

will be developed specifically for the new hardware and will be a part of the total Phase IV implementation process. The projected requirements baseline consists of functional user requirements or system enhancements that are not yet approved. Some of these may become approved and will then become part of the implementation baseline. (9:1)

In view of the above, the answer to the additional documentation question can not be a definitive yes or no. While the situation requires the examination of more information than the author has at the present time, the following is proposed.

For operational systems that have an established operational baseline and will be transitioned without modification, the transition/implementation should be treated no different from a modification to the system as currently handled under AFDSDC, Major Air Command (MAJCOM), Special Operating Agencies (SOA) procedures. A translation of these systems will produce little if any functional impact, therefore, it is not perceived necessary to create development documentation for systems which are already in operational use just for the sake of documenting CM baselines.

The same rationale holds for those systems for which enhancements will be made prior to implementation. However, the proposed enhancements should come under CM scrutiny and be included in the change proposal process so that the impact on the total transition process can be accurately assessed. It may not be necessary for approval action to be taken by the Configuration Control Board (CCB), but certainly the manager of each system should insure that any enhancements are necessary and that it would be disadvantageous to wait until conversion to the Phase IV hardware.

Any new development for the Phase IV hardware should be subject to the entire CM process, whether it is to be an enhancement to an existing system

or an entirely new requirement. If it is an add-on to an existing system only that aspect of it need be considered for formal CM. It is reasonable to anticipate that as additional and new requirements are generated for the Phase IV hardware, new systems will evolve to the extent that the CM baselines will be fully substantiated by appropriate documentation.

From the preceding discussion, it is clear that the CM function of identification for the Phase IV program is a complicated and elusive problem. A great deal of effort and coordination will have to be put into this function to insure that the efforts of the various organizations involved are using the same basis and are directed toward a common goal.

Configuration Control: The process of configuration control should also be based on the conversion baselines described by the Phase IV PMO. Once the transition baseline is identified and prior to implementation of the Phase IV hardware, changes should be processed and approved at the lowest appropriate level. Existing systems will continue to encounter processing problems that can be fixed by minor code changes. These changes would not require CCB approval since they are Class II type changes as discussed in Chapter III. These changes do not affect the functional nor system operation. However, the change processing procedure needs to be sufficiently defined to insure that adequate documentation accompanies the change.

Also, Class I type changes which affect only the transition baseline would not require CCB action. However, these changes must be approved at such a level that the change can be assessed for the impact on systems prior to Phase IV implementation as well as problems created by the change for transition to the new hardware. This level most likely would be the Single Manager for the MAJCOM, SOA systems, or the ADPS Manager at AFDSDC for standard systems.[1] Approving authorities should forward these changes to

the Phase IV configuration manager for information and recording. It may be advisable in some instances to forward decision responsibility to the CCB if there is an impact on the overall conversion effort.

Under the implementation baseline, new development will come under CM change control procedures. Once baselines are established for new CPCIs, then as the development proceeds, any changes to the baseline will be controlled. Class II changes may be approved by the ADPS manager or Single Manager, but Class I changes should be processed through the CCB. Likewise, any projected requirements that become part of the impelementation baseline will come under the control of the Phase IV configuration manager.

The CCB occupies an important position in the Phase IV development. The following is a suggested membership for the CCB:

Phase IV Program Manager	Chairman
Phase IV Deputy Program Manager	Alternate Chairman
Chief System Engineering	PMO
Chief Program Control	PMO
Chief Configuration Management	PMO*
ADPS Manager or Single Manager	AFDSDC/MAJCOM**
Functional Representative	AFDSDC/HQ USAF***

*The configuration manager may or may not be a full member. In either case, he acts as a secretariat for the CCB and provides the necessary administra- support.

1. One individual for each MAJCOM and SOA is designated as the Single Manager responsible for all ADP systems within his command or activity. For standard systems, which are primarily developed by AFDSDC, a responsible official is designated as the ADPS Manager for each ADPS program, such as the B3500 program.

**The manager whose system is affected by the change will be designated as a member of the CCB by the chairman for review of his system.

***A functional representative whose function is affected will be designed as a member of the CCB by the chairman. This representative could be selected from either the functional personnel at AFDSDC cr the Air Staff, or at the discretion of the chairman both could be included.

It is not the role of the CCB to make policy or initiate changes. Its function is to assess the impact of a change, insure that an adequate evaluation has been made, that all interfaces have been examined and to recommend to the chairman approval/disapproval. The approval/disapproval authority rests solely with the chairman, the Program Manager. Once the chairman approves a change it is the task of the Configuration Management Office to insure that implementation action is initiated and to track the change through development to implementation.

Configuration Status Accounting: The effort to provide this record keeping activity, as well as maintaining status on the large number of systems currently in existence and proposed for the new hardware, will be substantial. This activity is the third CM function, Configuration Status Accounting. The author is not sufficiently knowledgeable of the Phase IV program to describe the particulars as to how to accomplish this task. Because of the large number of systems and the expected volume of changes, an automated record keeping system should be considered. AFDSDC uses an automated system to perform part of this task and it should be investigated

to determine its applicability to the Phase IV environment.

Reviews and Audits: In determining the reviews and audits process as discussed in Chapter III, consideration has to be given as to how the CPCI will be transitioned. For those CPCIs that will be translated without modification, no special reviews should be required other than to be included in status reviews to track their progress. If, however, modifications are made, those modifications should be subject to design reviews to insure that all interfaces have been examined. A modified FCA and PCA should be conducted in conjunction with the Quality Assurance activity to check the transitioned system against its Phase IV documentation.

Any new development should run the gamut of reviews and audits. Only when absolutely necessary should special reviews be conducted by the PMO. The PMO should first insure that AFDSDC, MAJCOM, or SOA internal procedures provide adequate reviews and audits and then the PMO should participate in those reviews. Joint reviews will help provide an additional avenue for communication and cooperation.

This chapter has provided some of the author's thoughts on how CM should apply to the Phase IV program. While a complete CM plan for the Phase IV program will have to go into much greater depth and detail, it is hoped that these thoughts can form a basis from which to develop the Phase IV Configuration Management Plan. It is believed that the text book CM functions, tailored for this program, can and should be used. The situation presents some unique challenges for the Configuration Manager, but the use of CM in major defense systems provides some valuable insight into the problems that will be faced and gives some hints as to how a solution to these problems can be developed.

CHAPTER V

Summary and Conclusions

Summary: This paper has looked at Configuration Management from three different perspectives. First, from the viewpoint of regulatory documents, mostly pertaining to major defense system development, describing what CM was, and where and how it was to be applied. Next, the definitions in the regulatory documents were expanded and discussed in the environment of the development of a computer system. While the Phase IV program is not a classical development program, CM will be a necessary function for successful implementation.

Conclusions: One of the objectives in preparing this paper was to learn more about the subject of CM and become more familiar with the applicable directives. This objective was accomplished. The author was not aware of the number of directives and other documents that pertain to the CM function. While most of these directives are related to major defense systems development, it was learned that the Air Force has recently spent considerable effort in examining CM techniques to apply to computer systems development. A number of documents referred to in this paper are new or are still in draft form. Concern for adequate CM of software for both embedded computer systems and general purpose systems is growing as attested by these documents, workshops and published articles.

A second objective was to determine if CM principles in the major defense system environment could be applied to the development of computer systems. It is concluded that they not only can be, but that it is being done. Referring again to the Air Force documents under development by the Directorate of Data Automation, they have borrowed heavily from the major

defense system documents. Also, some major defense contractors have applied these techniques to their own software development. It must be kept in mind, however, that there are differences in managing software as opposed to hardware so some adaptation, mostly in procedure, is necessary.

Thirdly, it is concluded that CM principles can be applied to the Phase IV program. The program has some unique problems, but the CM principles can still be applied with some adaptation of the procedures and methodology.

Configuration Management is like any other discipline. If the techniques and procedures are realistically constructed, tailored to the situation, and once established, adherred to and followed and have the support of the participants, then CM can be a valuable part of the total management of a program. If instead, it is considered only a necessary evil and not followed, then it becomes a yoke. CM, properly applied, can make a valuable contribution to the successful development of future computer systems.

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